
Oxygen Transport Membrane Based OxyCombustion for CO₂ Capture from Coal Power Plants

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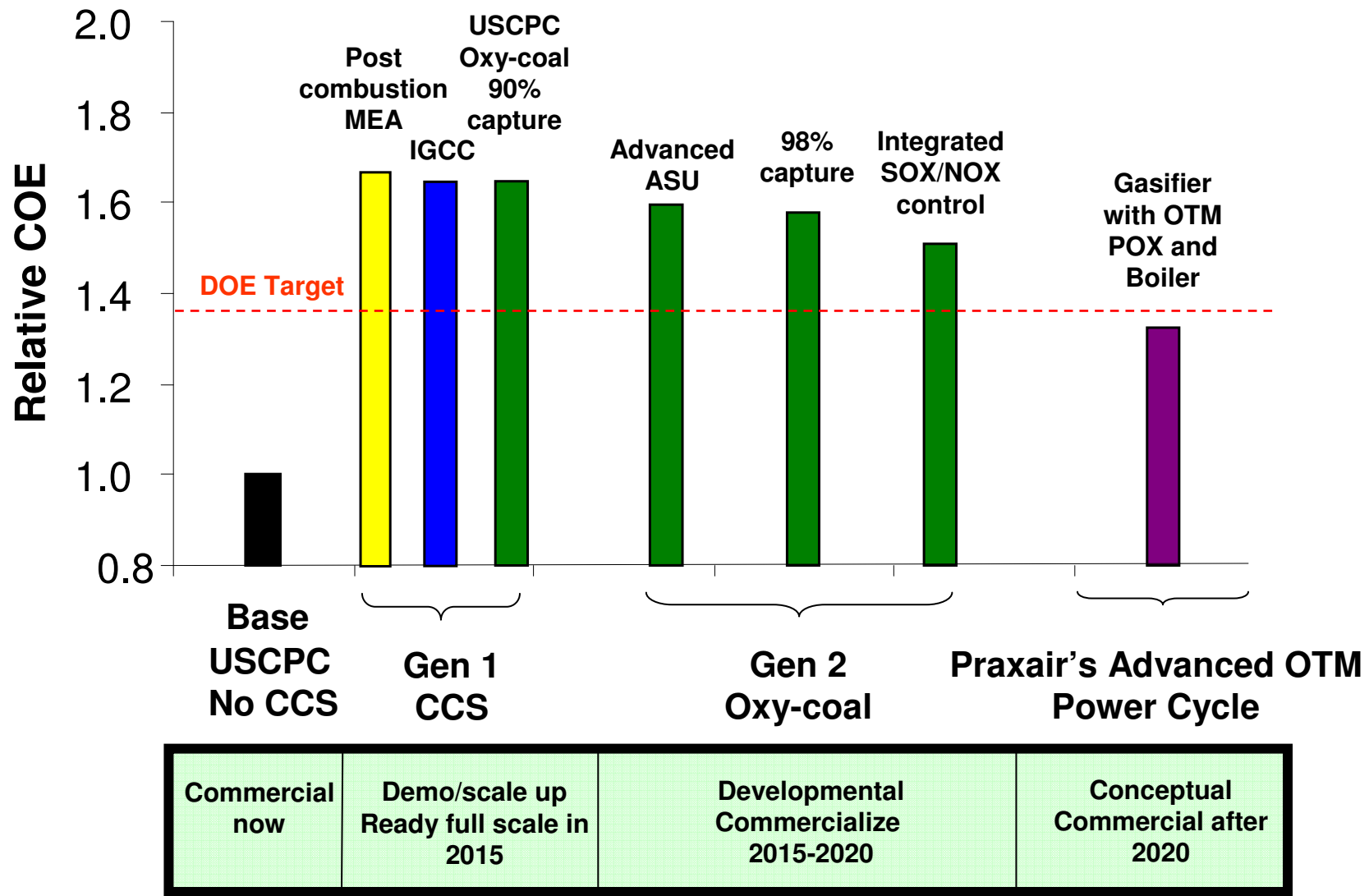
Praxair Clean Coal Technologies

Oxy Coal Combustion

- Oxygen Supply
- CO₂ Capture
- Oxy-Coal Burners
- High Temperature Coatings
- Tar Mitigation Solutions
- Oxygen Transport Membrane (OTM)

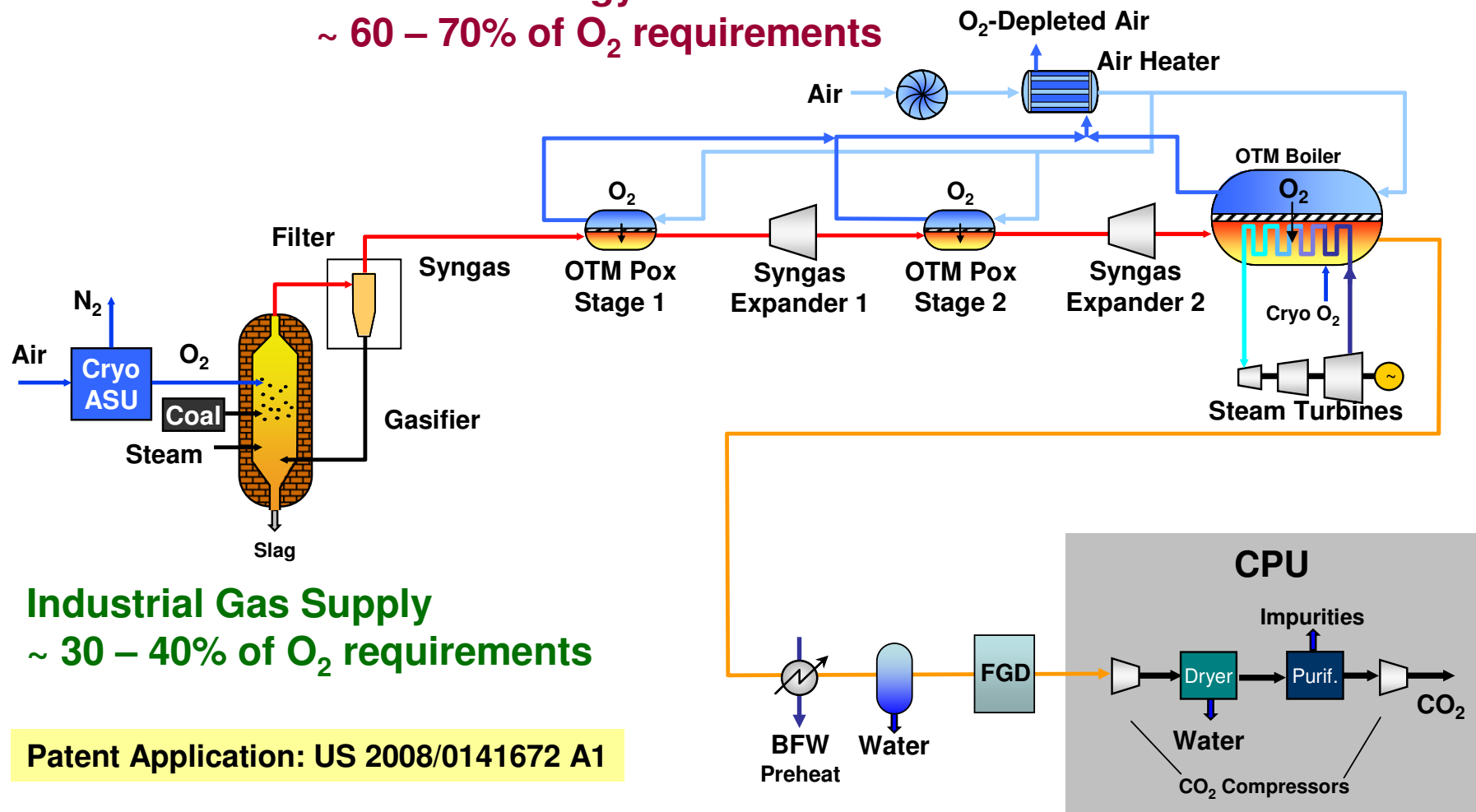
- Fortune 300 company with over \$10 billion revenues in 2008
- One of the leading industrial gas suppliers in the world
- Largest industrial gas supplier in North and South America

Advancing Oxyfuel Technology – Relative COE



OTM Advanced power cycle

OTM Technology
~ 60 – 70% of O₂ requirements



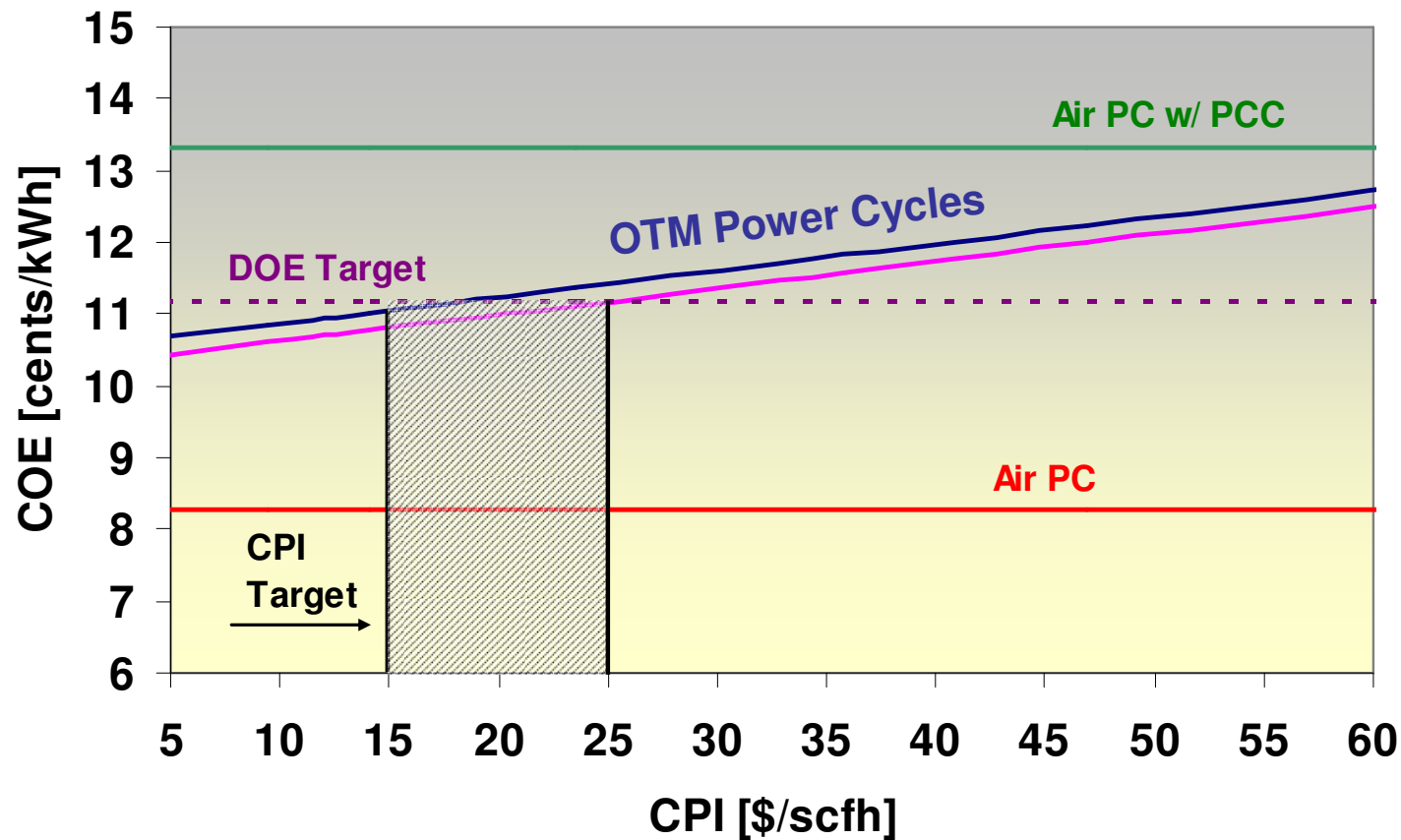
Industrial Gas Supply
~ 30 – 40% of O₂ requirements

Patent Application: US 2008/0141672 A1

OTM Power Cycle - Advantages

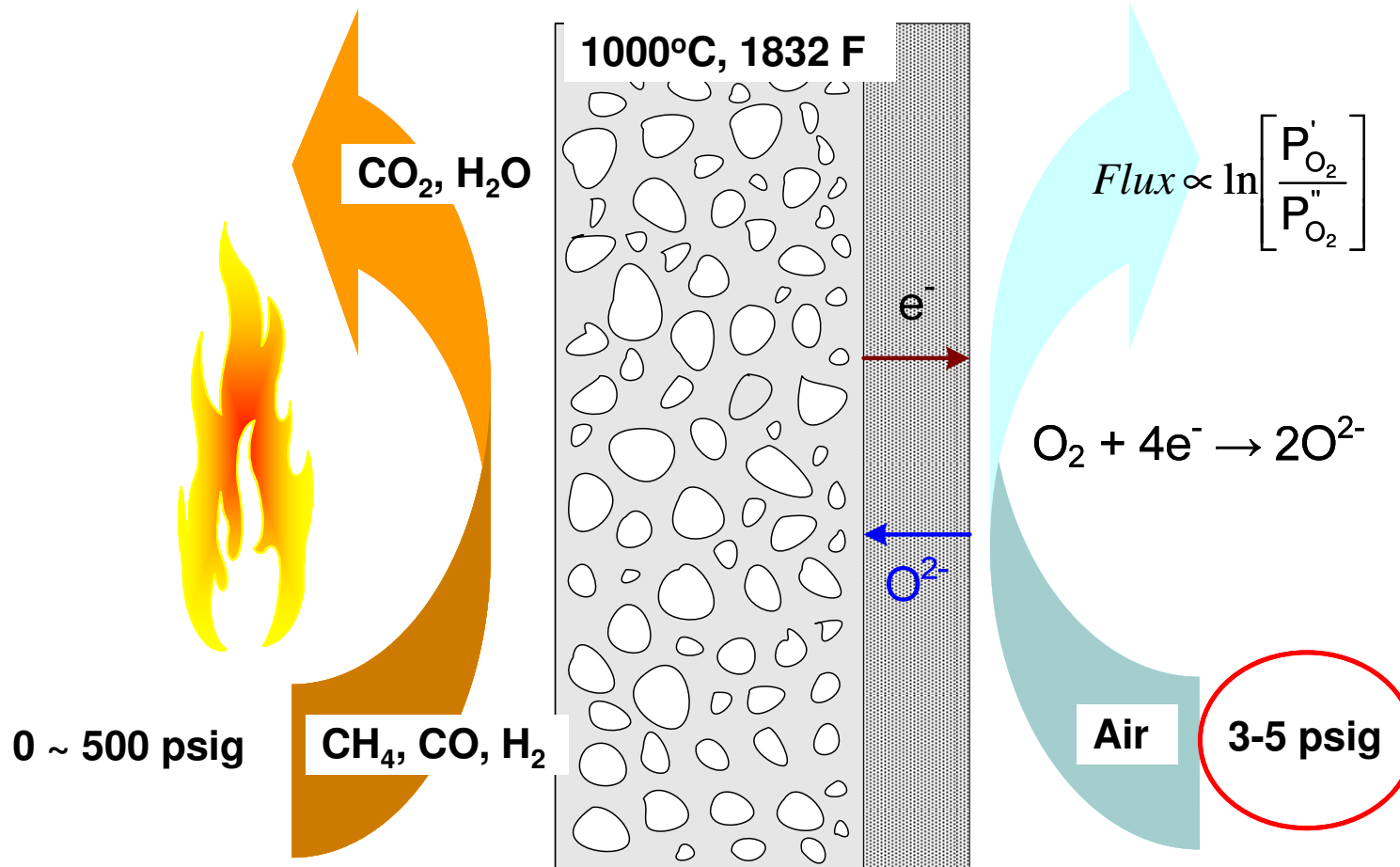
- OTM O₂ consumes ~75% less power than cryogenic ASU O₂
- Thermal energy of synthesis gas fully utilized (no quench)
- No flue gas recycle required
- High efficiency steam cycle can be used
- Latent heat recovery from flue gas

OTM Process Economics



- $\text{CPI } (\$/\text{scfh}) = \text{Cost } (\$/\text{sq.ft}) / \text{Performance } (\text{scfh}/\text{sq.ft})$
- Assumption: Coal price \$3/MMBTU

OTM Principle of Operation



Oxy-Combustion with OTM Oxygen Separation

OTM Materials

OTM Materials

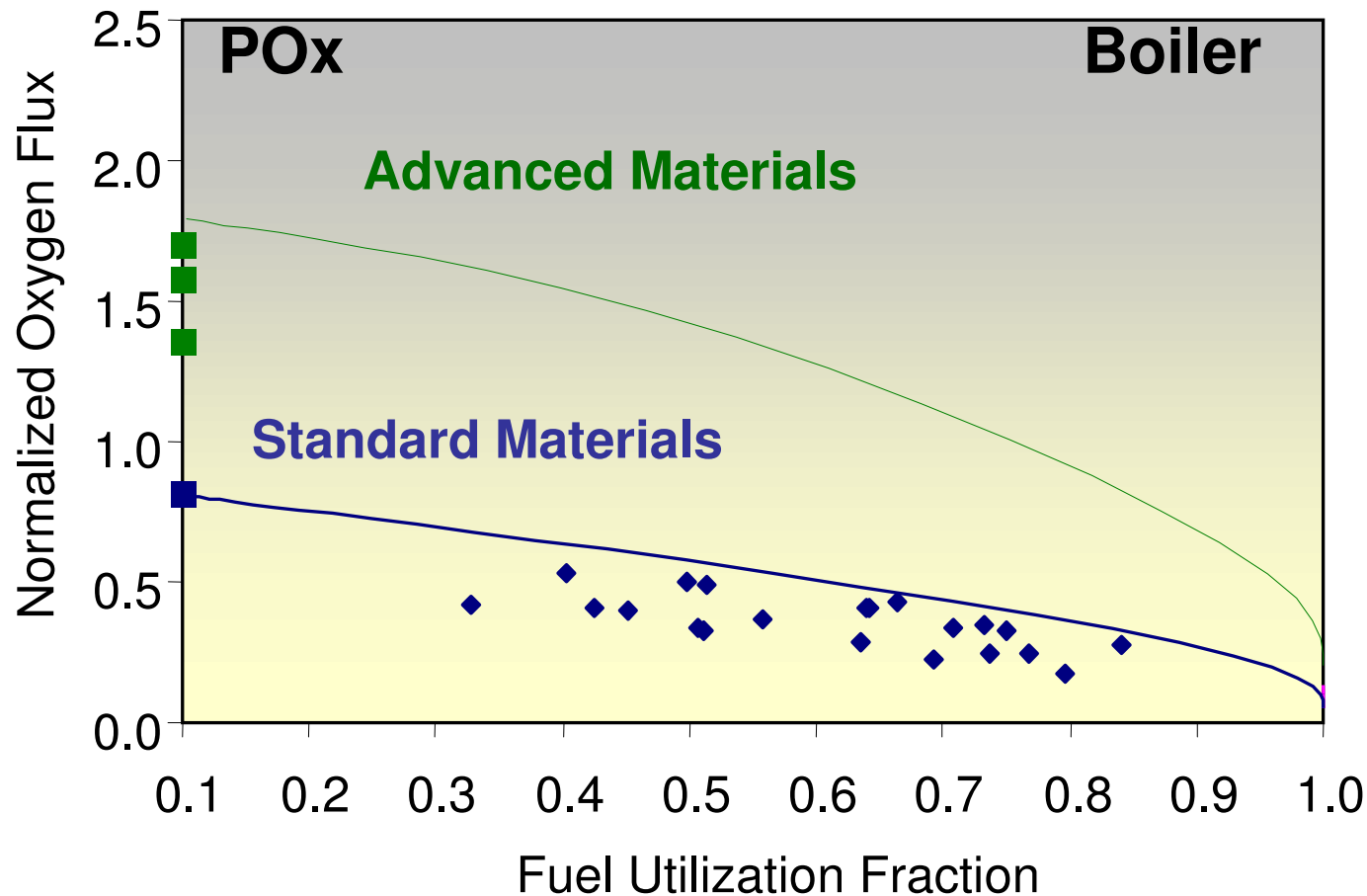
Patent Application: US 2008/0047431 A1

- **Porous Support**
 - Doped Zirconia
- **Separation/Reaction Layer**
 - Dual phase: metallic oxide & doped Zirconia

Advanced OTM Materials

- **Porous Support:** Improved mass transfer characteristics
- **Separation/Reaction Layer:** Improved fuel oxidation rates

OTM Performance

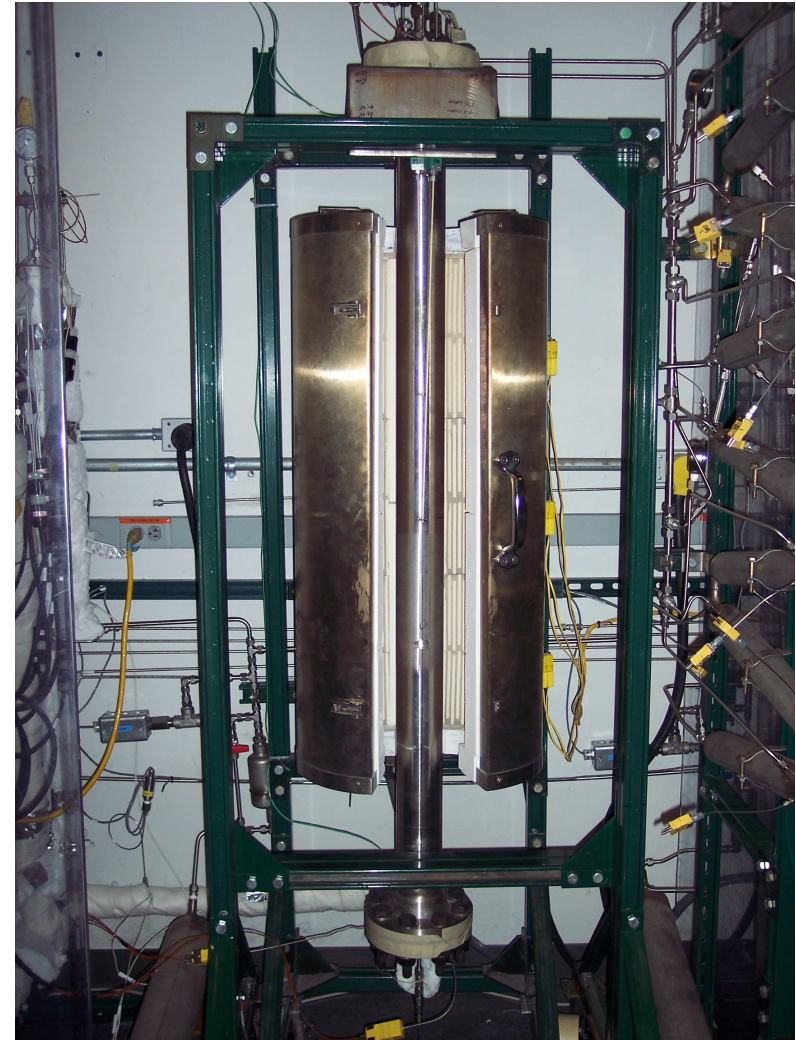


Incorporate advanced material system into full range of laboratory samples

OTM Testing Facilities

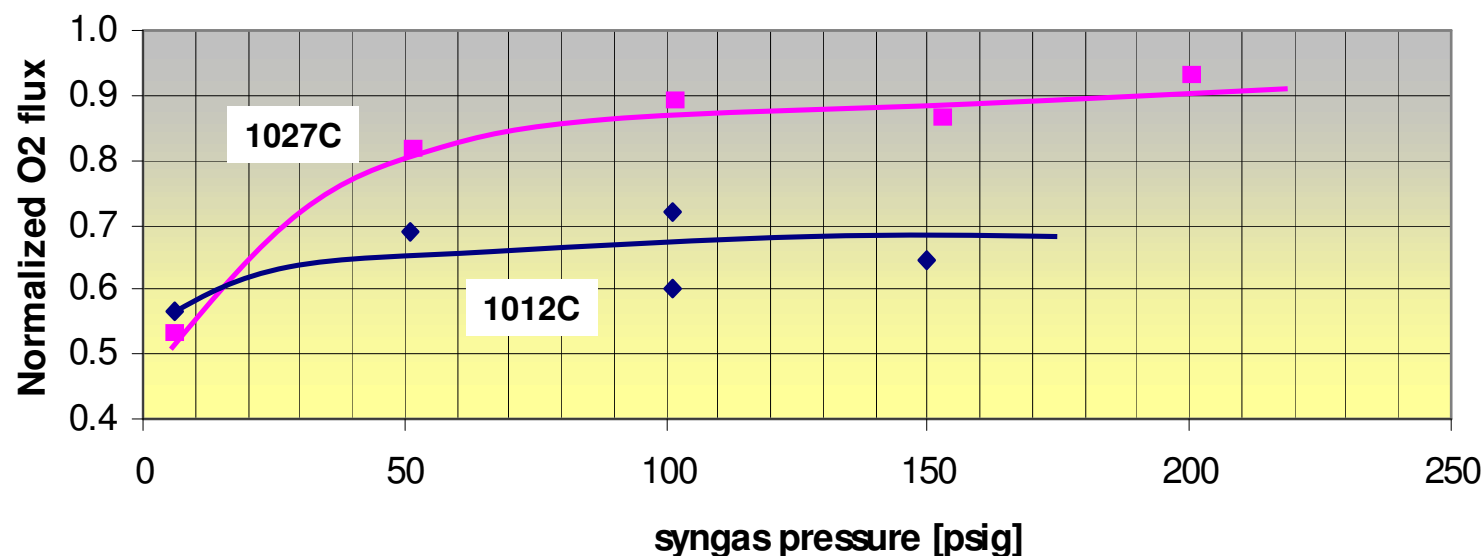
Praxair High / Low Pressure Reactors

- Single tube
- Up to 1000 °C
- Up to 200 PSI outside of tube
- Stability in sulfur



OTM High Pressure Reactor
Praxair

OTM Performance



Testing Conditions

- Standard material set
- (H₂, CO, CH₄, CO₂, H₂O) w/ 1% H₂S, 560 ppm COS,
- 200 psi fuel, atmospheric air

Key Milestone: Stable Performance with H₂S and COS

OTM Testing Facilities

Utah OTM coal reactor

- Configuration
 - Multiple OTM tubes
 - Solid fuel
 - Performance/stability
- Status
 - Construction complete
 - Undergoing preliminary tests
 - gaseous fuels
 - Preparing for solid fuel tests



OTM Coal Reactor
University of Utah

Summary

- **Step-change technology**
 - Reduced O₂ power cost (~75%)
 - Reliability at pressure & with gaseous fuel impurities
- **Significant challenges / Next Steps**
 - Oxygen flux improvement while retaining robust tubes
 - Understanding OTM Manufacturing costs (\$/sq. ft) (Phase II) & meeting manufacturing cost targets
 - Design/engineering of a large scale OTM boiler (Phase II)

Thank you.

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